High performance gasification with the two-stage gasifier

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Based on more than 15 years of research and practical experience, the Technical University of Denmark (DTU) and Cowi Consulting Engineers and Planners AS are able to present the proven two-stage gasification process, a concept for high efficiency gasification of biomass producing negligible amounts of tars.

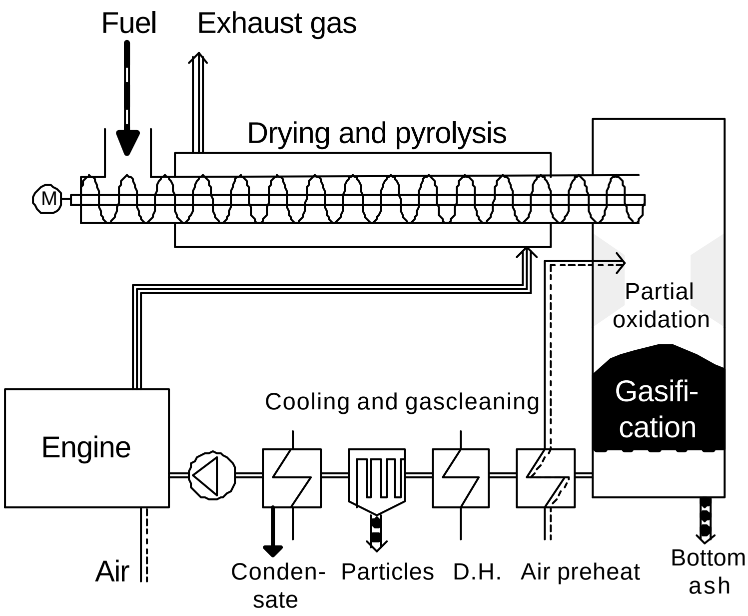

Figure 1. The two-stage gasification process developed and tested at the DTU

The two-stage gasification pilot plant was developed at the Department of Mechanical Engineering, Technical University of Denmark. In the two-stage gasification process (Fig. 1), the pyrolysis and the gasification processes are separated into two different units. In between the pyrolysis and the gasification, volatiles from the pyrolysis are partially oxidised.

Drying and pyrolysis
The pyrolysis unit consist of a transport screw with external heating (heated by exhaust gas from the engine). In the pyrolysis unit the volatiles escape from the fuel at temperatures below 600 ?C leaving solid coke. The residence time is 15 – 30 minutes.

Partial oxidation
At the end of the pyrolysis screw, the coke and the volatiles fall through the high temperature (1100 – 1300 ?C) partial oxidation zone directly into the fixed bed gasification chamber. Adding preheated air in a turbulent swirl causes the partial oxidation of the volatiles. Hereby a cracking of the pyrolysis tar will take place.

Gasification
The char is gasified in the down-draft gasification reactor. H_2O and CO_2 from the partial oxidation act as gasification agents to convert the char into combustible gasses which reduce the risk of channelling. The char bed is supported by a grid through which the produced gas escapes at approximately 750 ?C.

Gas cooling and cleaning
After coarse particle removal in a cyclone, the gas is cooled in a heat exchanger to 100 ?C. Soot particles are removed in a bag house filter before the gas is cooled in a condensing cooler to 45 ?C. The produced condensed water has a moderate content of ammonia, but can be led directly into the municipal sewage system without any treatment [1],[2]. Particles in the gas are present in amounts of 300-800 mg/Nm^3, the major fraction being soot [3]. Due to the low tar content using a simple bag filter the content of soot is reduced to 10-20 mg/Nm^3[4]

Engine
Investigation running a modified diesel engine fuelled by the gas shows, that high efficiencies and low emissions are obtainable [5].

Heat exchanging
The heat from cooling of the exhaust gas from the engine and from cooling of the product gas is used to dry and pyrolyse the fuel and for preheat the air. The fuel-to-cold gas conversion efficiency reaches 90% - 95% by heat exchanging the process streams [6]. This efficiency is about 10-20% higher that of other known gasification processes.

Tar reduction
The partial oxidation of the volatiles reduces the amount of tar dramatically [7], and the passage through the char bed reduces the tar content even further [8]. Even without gas cleanup, the tar content is below 25 mg/Nm^3 [6]. These are mainly tertiary tars or "heavy tars" with high boiling points.

Scale up
The two-stage gasification process have been demonstrated in scales ranging from 5 to 400 kW. The process can be scaled up to several megawatts and based on fluid bed technology a 20 MW two-stage gasifier is in the design phase. A continuously running demonstration plant based on the two-stage fixed-bed gasification process is under construction in Denmark.

Conclusions
A two-stage gasification process has been developed and demonstrated. The process provides a plant with high efficiency and stable operation conditions. Further more the gas produced have an extremely low content of tar and particles and a trouble free condensate.

References

[1] L. la C. Jansen & K. Jönsson. Nitrification inhibition of tar-water from wood chips gasifiers. 1st World Biomass Conference and Technology Exhibition, 5-9 June 2000, Seville.
[2] J.D. Bentzen & U. Henriksen. Condensate from a two-stage gasifier. 1st World Biomass Conference and Technology Exhibition, 5-9 June 2000, Seville.
[3] C. Hindsgaul, J. Schramm, L. Gratz, U. Henriksen & J.D. Bentzen. Physical and Chemical Characterization of Particles in Producer Gas from Wood Chips
[4] C. Hindsgaul. Low Temperature Particle Filtration of Producer Gas with Low Tar Content. Department of Mechanical Engineering, Technical University of Denmark, ET-ES-2000-5.
[5] J. Ahrenfeldt, U. Henriksen & J. Schramm. Experimental on Wood Gas Engines. November 2000. Department of Mechanical Engineering, Technical University of Denmark, ET-ES-2000-4.
[6] J.D. Bentzen & U. Henriksen. Optimised two-stage gasifier. 1st World Biomass Conference and Technology Exhibition, 5-9 June 2000, Seville.
[7] Brandt, P. & Henriksen, U. (1998). Decomposition of tar in pyrolysis gas by partial oxidation and thermal cracking. Part 2, 10. European conference and technology exhibition, Würzburg, (Germany), 8-11 June 1998
[8] P. Brandt, E. Larsen and U. Henriksen. High Tar Reduction in a Two-stage Gasifier. Energy & Fuels 2000, Vol. 14, Issue 4, pp- 816-819.